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Research Document 2005/085 | **Document de recherche 2005/085**

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A preliminary examination of spawning suppression in relation to recruitment in NAFO Subdivision 3Ps cod (*Gadus morhua*)

Examen préliminaire de la diminution de l'activité reproductrice par rapport au recrutement chez la morue (*Gadus morhua*) de la sous-division 3Ps de l'OPANO

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ISSN 1499-3848 (Printed / Imprimé)
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106-04526/

ABSTRACT

Recruitment in 3Ps cod has been relatively weak over the last decade or more. Only 2 strong year classes have been produced from 1990-2001, even though the SSB has been relatively large since 1996. One possible factor causing low recruitment is that not all sexually mature fish may spawn in every year. Cod in 3Ps have been found to suppress spawning at frequencies as high as 46% in some years. The purpose of this study is to recalculate SSB for 3Ps cod, including only female fish that were predicted to spawn and to determine if low recruitment in some years could be related to spawning suppression. On average 84% of female cod in 3Ps were estimated to spawn each year with little variability in this estimate from year to year. However there were a few years (1980, 1985, 1986 and 2001) in which the proportion spawning was lower than 80%. There was little or no relationship between recruitment and the proportion of fish spawning. The lack of effect may be the result of a reasonably constant rate of spawning suppression.

RÉSUMÉ

Le recrutement de la morue de 3Ps a été relativement faible pendant la dernière décennie et même avant. Seulement deux fortes classes d'âge ont été produites entre 1990 et 2001, et ce, même si la BSR est relativement importante depuis 1996. L'une des causes possibles de ce faible recrutement est que ce ne sont pas tous les poissons ayant la maturité sexuelle qui se reproduisent chaque année. On a constaté, chez la morue de 3Ps, une diminution de l'activité reproductrice pouvant atteindre 46 % certaines années. Le but de cette étude est de recalculer la BSR pour la morue de 3Ps, en n'incluant que les sujets femelles qui devraient se reproduire, et de déterminer si le faible recrutement de certaines années pourrait être associé à une diminution de l'activité reproductrice. On estime qu'en moyenne 84 % des morues femelles de 3Ps se reproduisent tous les ans – la variabilité dans cette estimation est faible d'une année à l'autre. Toutefois, on constate que, certaines années (1980, 1985, 1986 et 2001), la proportion d'individus qui se reproduisent est inférieure à 80 %. Il n'existe que peu ou pas de relation entre le recrutement et la proportion de sujets qui se reproduisent. Or, le manque d'effet pourrait être le résultat d'un taux assez constant de diminution de l'activité reproductrice.

INTRODUCTION

Recruitment in 3Ps cod has been relatively weak over the last decade or more. Only 2 strong year classes have been produced from 1990-2001, even though the SSB has been relatively large since 1996. As noted by Brattey et al (2004), SSB may not be the best indicator of reproductive potential. A decline in age at maturity combined with the current age structure of the population has resulted in an SSB composed of a higher proportion of younger females (Brattey et al, 2004; Morgan and Brattey, 2005). Age composition is thought to be an important determinant of reproductive success with SSB with a younger, less diverse age structure having less success (Marteinsdottir and Thorarinsson, 1998; Trippel, 1998; Marshall et al. 1998).

Another possible factor is that not all fish may spawn in every year. There is increasing evidence that adult fish may not always spawn in consecutive years when faced with adverse environmental conditions (reviewed by Rideout et al. 2005). Spawning suppression is usually caused by poor nutritional condition due to reduced prey availability or low availability of certain types of prey. Cod in 3Ps have been found to suppress spawning at frequencies as high as 46% in some years (Rideout, Morgan and Lilly unpublished data). This suppression of spawning is related to condition with fewer fish estimated to spawn at lower relative liver condition.

In this study we recalculated SSB for 3Ps cod, including only female fish that were predicted to spawn, and determined if low recruitment in some years could be related to spawning suppression.

Materials and methods

The population numbers at age from VPAs reported in Brattey et al (2004) were used in the analyses. Results from VPAs assuming a flat topped and domed partial recruitment were both examined. Results were very similar and only the results from the analyses using population numbers from VPA assuming a flat topped partial recruitment will be discussed in detail here.

Morgan and Brattey (2005) found that sex ratio varies by age and cohort in 3Ps cod. The population numbers were adjusted by the estimated sex ratio to give female only SSB. This results in a similar trend in SSB (Figure 1).

In this study, only those fish that had already begun (or finished) spawning and those fish that were estimated to spawn in the current season were included in calculations of SSB. That is, females that were estimated to suppress spawning in a particular year were excluded from the estimate of SSB for that year. As a starting point, the number of fish that had already begun to spawn or had finished spawning were calculated at each age in each year. This was done by multiplying the proportion of fish in the spawning or spent condition at each age in each year

as calculated from research vessel data by the number of females at each age in each year.

The second step was to estimate what proportion of the remaining females will spawn. The probability of spawning in 3Ps cod is related to condition by the equation (Rideout, Morgan and Lilly unpublished data):

$$f = \frac{1}{1+\exp^{-(-1.0689+2.4604x)}}$$

where x is relative liver condition. Length-independent indices of liver condition were calculated for each female that had not yet spawned as:

$$LK_r = LW / \hat{LW}$$

where LW is liver weight and $\hat{LW}$ is the predicted liver weight, respectively, from the following length/weight relationship:

Log LW=intercept + log(L) + $(\log(L))^2$

Then the average relative liver condition for each age in each year was calculated to produce estimated proportion spawning using the relation between spawning probability and condition described above. The number of females estimated to spawn of those that had not yet begun (or finished) spawning was calculated by multiplying this proportion by the number of females remaining after the number that had already started or finished spawning had been removed. The final spawning stock number was then the number of females that were estimated to spawn plus those that had already started or finished spawning.

Recruits per spawner from female SSB that include all adult females was then compared to the proportion of females that were estimated to spawn to determine if spawning suppression was influencing the level of recruitment.

Results and Discussion

On average 84% of female cod in 3Ps were estimated to spawn with a range from 70 to 92%. There was relatively little variability in this estimate from year to year (Figure 2). However there were a few years (1980, 1985, 1986 and 2001) in which the proportion spawning was lower than 80%.

The long term decline in recruitment is still apparent regardless of the estimate of SSB used (Figure 3). The most recent R/S is below average regardless of the estimate of SSB.

For the 4 years in which the proportion spawning was below 80%, 3 of the years had R/S less than the average when all adult females were included in the SSB.

However, R/S was also less than average in those years when only spawning females were included in the SSB, so including only spawning fish does not give a different perspective. There is also no correlation between the level of recruitment and the proportion spawning (Figure 4).

Although the proportion estimated to spawn differed between the VPAs with different partial recruitment assumptions, the overall results were the same. So the apparent lack of effect of the proportion spawning on recruitment was not the result of the VPA assumptions.

The lack of effect may be the result of a relatively constant rate of spawning suppression. Also it may be that the effect of the change in age structure of the population has a much greater role than spawning suppression. Alternatively density independent factors such as temperature may be more important in determining the level of recruitment in this population.

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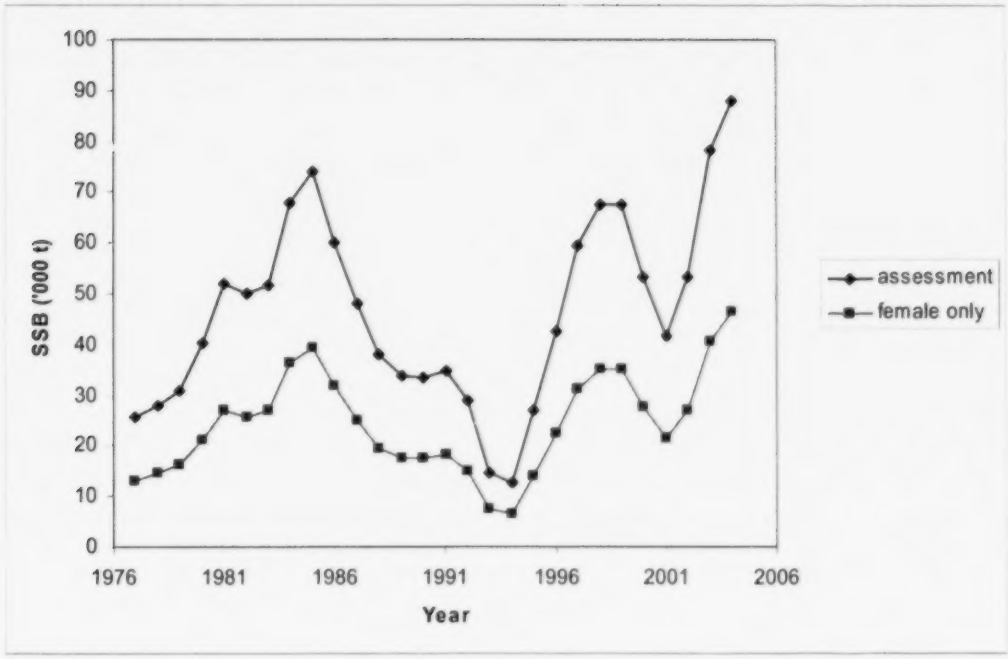

Figure 1. Spawning stock biomass in which all fish are included in the estimate (assessment) and in which the population numbers are adjusted by the estimated sex ratio to give female only SSB.

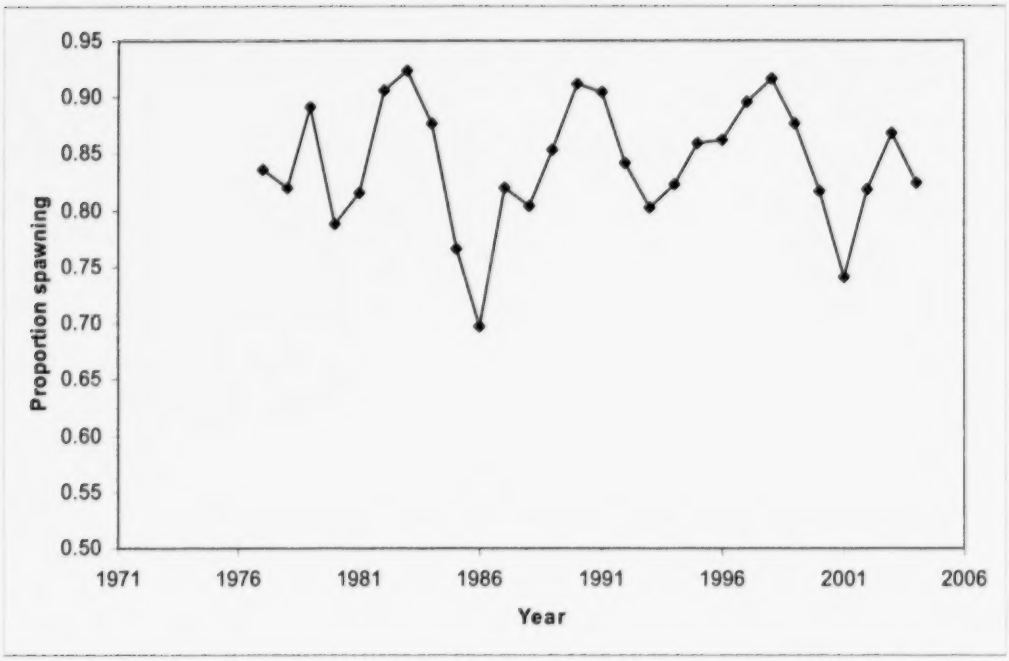

Figure 2. The proportion of adult females estimated to spawn in 3Ps in each year from 1977 to 2004.

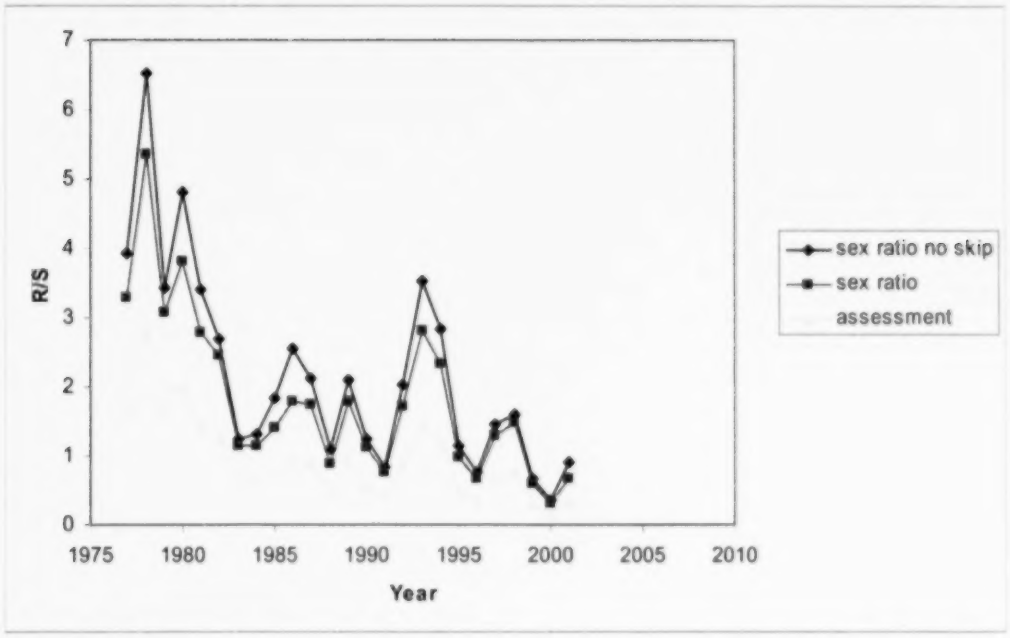

Figure 3. Recruits per spawner (R/S) in each year for 3 estimates of SSB: including both males and females in the estimate (but female only maturity ogive: assessment), only including adult females (sex ratio) and only including females that are estimated to spawn (sex ratio no skip).

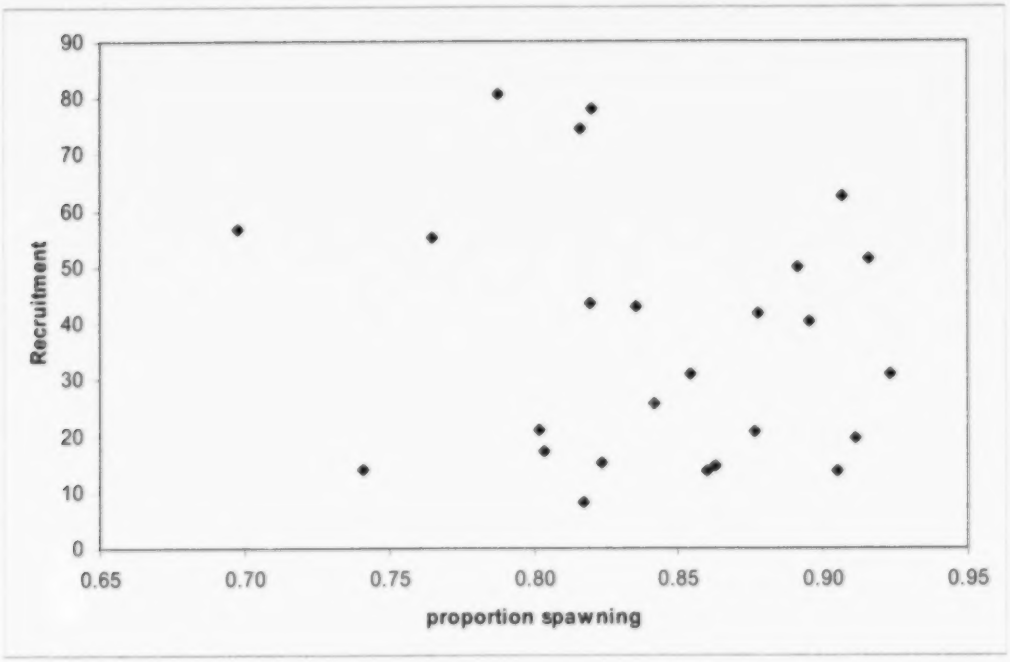

Figure 4. Recruitment from VPA and the proportion of adult females estimated to spawn.